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SOIL SURVEYS IN PORT HOPE, ONTARIO

A SUMMARY OF STUDIES BY THE ONTARIO MINISTRY OF THE ENVIRONMENT

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INTRODUCTION

This report summarizes the results of two Ministry reports on the subject of soil surveys taken in the vicinity of Cameco Resources[1], Port Hope, Ontario.

The reports, entitled "Phytotoxicology[2] Assessment Surveys in the Vicinity of Eldorado Resources Ltd., Port Hope, 1986 and 1987" and subsequently the "Assessment of Human Health Risk of Reported Soil Levels of Metals and Radionuclides in Port Hope," were completed in 1989 and 1991 respectively.

SUMMARIES OF THE MINISTRY STUDIES

1.0 Phytotoxicology Assessment Surveys in the Vicinity of Eldorado Resources Ltd., Port Hope, 1986 and 1987.

1.1 BACKGROUND

The Phytotoxicology Section of the Air Resources Branch of the Ministry of the Environment has conducted annual assessment surveys in Port Hope since 1974. The purpose of these surveys was to monitor the impact of emissions from Eldorado Resources Ltd. (now known as Cameco) on the local terrestrial ecosystem. Survey activities have included the collection and analysis of surface soil and tree foliage, the deployment of ion-receptor moss bags and inspection of vegetation for the presence of characteristic air pollution injury symptoms. Also, complaint investigations regarding soil or vegetation contamination or injury have been conducted as requested by the public. This report summarizes the results of the Phytotoxicology assessment surveys conducted in 1986 and 1987.

In 1986, a soil survey was conducted at 36 sites throughout Port Hope to determine the severity and extent of uranium, arsenic, cadmium, chromium, copper, nickel, lead and zinc contamination of surface soil. Most of these soil sample sites were located on residential or municipal lawns. Grass was also collected from the same 36 sites and was analyzed for the same eight elements.

The 1986 soil survey was repeated in 1987 at 18 of the original 36 sample sites. Also, 23 new sites were sampled in 1987, primarily from areas of elevated levels identified in the 1986 survey. In addition to the eight elements for which data were obtained in 1986, the 1987 soil samples were analyzed for total iron, cobalt, antimony and selenium. Selected 1987 soil samples also were analyzed for the radionuclides[3] uranium 238 (^{238}U), thorium 228 (^{228}Th), radium 226 (^{226}Ra), radium 228 (^{228}Ra), potassium 40 (^{40}K) and lead 210 (^{210}Pb).

1.2 RESULTS AND DISCUSSION

These surveys confirmed that Eldorado Resources Limited (ERL, now Cameco) is currently emitting uranium, fluorine and to a lesser extent arsenic to the atmosphere. Fluoride emissions are still high enough to injure vegetation, even though emission rates have declined from the 1970s and early 1980s.

Surface soil concentrations of uranium, copper, nickel, lead, zinc, iron, arsenic, cobalt, chromium and antimony exceeded Phytotoxicology guidelines. The most frequent and severe exceedances were detected for uranium, arsenic and antimony. Soil concentrations of these elements are high enough at some sites to be phytotoxic to some plants. In addition, the radionuclides 226Ra, 210Pb and 238U were detected in soil at activities which consistently exceeded reported background values. The soil contamination gradients for uranium, arsenic, antimony, 238U, 226Ra and 210Pb clearly indicate that the ERL/Cameco complex is the main source. The areas of highest soil contamination are mostly within 500 metres of ERL/Cameco and correlate well with the zone of greatest long term deposition of atmospheric emissions as estimated by Atmospheric Environment Services (AES) dispersion modellers.

In the past, Health and Welfare Canada has studied vegetable produce grown in Port Hope gardens contaminated with uranium and radium. They concluded that consumption of the crops represents neither a chemical nor a radiological hazard. However, the implications of potential health effects from exposure to soil contaminated with other elements and radionuclides at the concentrations encountered in some areas of Port Hope have not been fully examined (at the time of this report), by the Ministry of the Environment.

It was recommended, therefore, that the soil survey data be reviewed by the appropriate environmental health and medical authorities for potential health implications to assist in determining whether or not remedial actions are required.

The subsequent assessment and resulting report were undertaken on the basis of this recommendation.

2.0 Assessment of Human Health Risk of Reported Soil Levels of Metals and Radionuclides in Port Hope

2.1 Background

This document represents an assessment of potential exposure and environmental health risks associated with elevated levels of eleven metals and three radionuclides in the soil.

The substances assessed are listed below:

Metals and Radionuclides Assessed

METALS	RADIONUCLIDES
Arsenic (As)	Radium 226 (^{226}Ra)
Antimony (Sb)	Lead 210 (^{210}Pb)
Uranium (U)	Uranium 238 (^{238}U)
Lead (Pb)	
Chromium (Cr)	
Copper (Cu)	
Nickel (Ni)	
Cadmium (Cd)	
Cobalt (Co)	
Selenium (Se)	
Zinc (Zn)	

The assessment was developed because some of the reported levels of a number of metals exceeded the Ministry of the Environment's Upper Limit of Normal[4] Guidelines and Guidelines for Decommissioning[5] of Industrial Sites. In addition, the survey identified three radionuclides (226Ra, 210Pb and 238U) as consistently exceeding reported background levels.

The undertaking of the analysis is in keeping with the concept of application of upper limit of normal guidelines, which if exceeded lead to investigation on a case-by-case basis.

2.1.1 Multimedia Risk Assessment Approach

It is well established that humans can be exposed to metals from a variety of sources including drinking water, food, ambient air soils/dusts and consumer products. In order to evaluate the health significance of exposure through a particular pathway or source (in this case, soil), it is necessary to begin to understand the total exposure picture from all routes. The multimedia risk assessment approach, which considers total exposure through multiple pathways, was used to evaluate human exposure to each of the metals.

Exposure estimates for each significant pathway are developed for adults and young children. Young children are assessed as a special population subgroup because of their greater contact with, and direct ingestion of, soil and dusts. As well, children may be more sensitive to the effects of certain contaminants.

The relative contribution of soil/dust ingestion to total exposure is assessed relative to the intake from other pathways (food, air, drinking water). The latter are modelled using existing monitoring information or assumed concentrations together with values for human receptor characteristics (i.e. daily breathing volumes). Average exposures for each pathway are integrated to provide an estimate of potential total exposure.

The approach uses the available published information on contaminant levels in various media. Actual levels in Port Hope for media other than soil may differ from what is assumed or predicted. This information is then used to predict exposure for the typical individual in either the child or adult age groups. It should be noted that individual exposure patterns will vary widely depending on many factors such as diet, age, occupation, sex and personal behavior choices. The exposure estimates must be viewed in light of these provisions.

With respect to discrete exposures from the soils in question, human exposure and intake may occur through multiple pathways from the soil source. The most obvious for metals in soil are incidental soil/dust ingestion for children at play and adults engaging in certain activities (e.g. landscaping), contact through skin and indirect intake through the consumption of homegrown vegetables.

Intake by soil ingestion is quantitatively assessed for each metal. The primary exposure scenario is based on an assumption of continual daily exposure to the reported levels. This does not take into account indoor/outdoor exposure, seasonal variability, residence time in areas or land use (for example, if the ground is frozen or snow-covered, exposure is not continuous throughout the year). As a result, the calculated exposures will tend to overestimate actual exposures. Consideration of exposure under other scenarios is considered for specific metals in soils from recreational areas.

Other exposures examined were skin contact and home-grown produce consumption.

To characterize risk, the modelled exposures for adults and children were compared against existing acceptable intakes or oral reference doses for each metal. This applies to those toxic effects which exhibit a threshold. For carcinogenic (cancer causing) metals, where no "safe" level or threshold has been established, associated risk levels are determined.

For radionuclides, exposure is assessed through the most significant environmental routes of intake from soil (ingestion of soil and homegrown vegetables).

2.2 RESULTS AND DISCUSSION

2.2.1 Arsenic

Arsenic is a known human carcinogen. Ingestion of inorganic arsenic is associated with skin cancer in humans. The determination of risk related to soil exposure is based on this effect.

In Ontario, including Port Hope, average intakes of arsenic are expected to occur predominantly through the food pathway, accounting for approximately 90% of daily exposure. The average measured arsenic level in soil in the Port Hope surveys is 20 parts per million (ppm), with measured levels ranging from 2 to 234 ppm.

The majority of measurements fall below the average. The estimated average exposure to arsenic from soil based on this level would increase the total absorbed intake above background by 0.8 - 9.5% for children and 0.2 - 2% for adults. The predicted relative contribution of soil/dust to total daily intake for children and adults is 9% and 2% respectively.

In other words, the total exposure in Port Hope would not appear to be very different from exposures for other cities in Ontario.

Two types of analysis were used to examine the potential significance of these arsenic exposures.

1) The first type is based on United States Environmental Protection Agency (USEPA) skin cancer potency factors for ingested inorganic arsenic. The average daily intakes from soil/dust yield predictions of increased frequency of skin cancer of 0.0006 cases/year (0.05 over a lifetime) for a group or population the size of Port Hope (approximately 10,000). This assumes daily exposure to these concentrations over a lifetime.

   Calculated average individual incremental risks from arsenic in soil/dust are estimated at 1×10^{-5} (1 in 100,000) The corresponding risk level at 50 ppm is 2.5×10^{-5}. Concentrations of greater than 50 ppm are confined to two relatively small areas of Port Hope according to the SYMAP[6] contours.

   Risk levels in the 10^{-5} and 10^{-6} magnitude are generally thought of as negligible.

   Further, the potency factor used is derived from modelling methods which are generally recognized as conservative and therefore may tend to overestimate risk. In comparison, using the same potency factor, the risk level associated with daily ingestion of food is 2×10^{-4}, which is more than 10 times greater than the average soil/dust risk calculated here.

2) Total arsenic intake from all pathways, including soil, when compared to threshold levels, indicate exposures are within the range of detoxification as suggested by a model of arsenic metabolism.

   These exposures are also well below the provisional maximum permissable intake levels established by the World Health Organization.

- In summary, arsenic concentrations in soil were examined using two approaches. Estimated intakes from contact with these soils yield risk estimates in the range generally considered negligible and were below the WHO permissable intake.

2.2.2 Antimony

A complete quantitative assessment of antimony exposures was not possible given the lack of dietary exposure data. Confidence in the only available reference dose is also low.

Precise conclusions based on quantitative methods cannot be reached. Qualitatively, it may be considered that antimony is thought to behave biologically and chemically in a similar manner to arsenic but to be less toxic.

It is also likely that normal dietary intake would account for the bulk of exposure. The maximum concentration was associated with an area adjacent to the west bank of the Ganaraska River. Taking into consideration recreational exposure times, soil/dust intakes were calculated and are below the reference dose value.

- Based on these factors, antimony concentrations are not anticipated to pose a hazard in these areas.

2.2.3 Uranium

Exposure to uranium can result in two basic categories of effects: those associated with the radiobiological properties of uranium and those associated with its chemical properties. The available toxicological information suggests in general that chemical and not radiological effects may be assumed to be the limiting factor with respect to human health at environmental levels of exposure.

The principle health effect considered in the development of reference doses for oral exposure to uranium in humans is nephrotoxicity or kidney effect. Comparison of both discrete soil intake estimates and total daily intakes with current acceptable daily intakes/reference doses indicate that these exposures are well below the most conservative limits.

- It is concluded that exposure to uranium in soil would not be predicted to pose an untoward health hazard in these areas.

2.2.4 Lead

Young children are generally thought to be the most sensitive receptors of lead and will have the greatest potential contact with soils.

The principle potential health effects associated with lead at low levels of exposure involve inhibiting enzyme activity in red blood cells and subtle neurobehavioral deficits. There may not be a threshold or safe level for neurobehavioral/developmental effects in children. In other words, any exposure to lead may carry some degree of risk. People are exposed to lead through various pathways (food, water, consumer products, etc.) everyday.

The average concentration of lead in soil in Port Hope is 140 ppm, including all sites. Measured levels are typically less than 200 ppm, with most concentrations less than 100 ppm. Estimated exposures for children to lead in soil in Port Hope would be predicted, on average, to be less than exposures for other urban Ontario locations, where lead levels of several hundred ppm are not unusual. Average soil/dust exposures may account for 20-40% of daily exposure of children, with 50-75% through food.

The total combined exposure from all media is unlikely to be greater than the WHO provisional tolerable daily intake.

According to the SYMAP projections, concentrations of greater than 500 ppm are limited to two small confined areas. Modelled intake from soil at residential sites at 500 ppm would be about 75% of the tolerable daily intake (this assumes continuous daily exposure to that area). Taken together with other exposures, total intakes would be estimated at approximately 1.4 times the suggested intake limit.

As with antimony, the highest concentrations of lead are found in the area of the west bank of the Ganaraska River. Exposures from soil ingestion alone, based on the more reliable measurement (1300 ppm) and adjusted for time spent in the area, would fall within intake limits. However, if soil concentrations are several thousand ppm (as one highly variable sample taken in 1986 possibly suggests), then exposures could exceed tolerable intakes by several fold. Furthermore, with respect to the remediation of contamination around existing facilities, the Royal Society of Canada has recommended that levels of up to 1000 ppm should be acceptable for parklands and other areas to which children may have intermittent access.

- In summary, given the limited degree of contamination the soil levels of lead in these areas in general are not anticipated to pose a hazard. Extended contact with the site on the riverbank may result in exposures above tolerable intakes depending on the extent and level of contamination.

2.2.5 Chromium, Copper, Cadmium, Nickel, Cobalt and Selenium

The estimated average levels of chromium, copper, cadmium, nickel, cobalt and selenium in soil are not predicted to pose any appreciable health risk to persons living in these areas.

This is based on:

1) average estimated exposure via soil would result in intakes below the human oral acceptable intakes and reference doses for these metals;

2) soil/dust intakes represent less than 1% of the average exposure contribution;

3) nickel, chromium, copper and cobalt are essential dietary nutrients at low concentrations.

2.2.6 Zinc and Iron

Iron is not evaluated in the quantitative risk assessment because of the low hazard associated with iron intake and its known nutritional benefits.

Zinc is qualitatively assessed given its low level of toxicity to humans. Based on a comparison to recommended nutrient intakes for Canadians, the reported zinc levels are not believed to present any health implication.

2.2.7 Radionuclides Assessment

If ingested, radium 226 (^{226}Ra) and lead 210 (^{210}Pb) are stored in bone and present the potential risk of induction of bone cancer. The major ingestion pathways from soil are the ingestion of contaminated soil and the consumption of garden produce. With regard to soil and produce ingestion, it is concluded under reasonable assumptions that the annual radiation dose attributable to these radionuclides will be less than several percent of the population limits.

With respect to uranium 238 (^{238}U), chemical toxicity is thought to be the limiting effect for environmental exposures, although radiobiological effects can occur. The estimated average soil intake for a child is less than 0.1% of population exposure limits and occupational annual limits of intake.

3.0 CONCLUSIONS

Risk assessment methods were applied to the question of health implications of contaminated soil in the Port Hope area. Soil-related as well as other pathways of exposure were considered.

Exposures to the reported levels of uranium, antimony, chromium, copper, nickel, cadmium, cobalt, selenium, and zinc in Port Hope soils are not expected to result in adverse health consequences.

Oral exposure to arsenic in soil at the reported levels is estimated to result in incremental cancer risk levels in the negligible range (10^{-5}). Estimated exposures also fall well below suggested toxic thresholds for arsenic. For the two small areas within the greater than 50 ppm isopleths, assessment of exposure is these zones requires more definitive data.

Overall, contamination of soils with lead is quite limited. In general, the reported soil levels of lead are not anticipated to pose a hazard. The site with the highest concentrations of lead is located on the west bank of the Ganaraska River, a popular fishing area. Depending on the level and extent of contamination, as well as degree of contact with the site, potential exposures could exceed tolerable intakes (for children).

4.0 FOLLOW UP INVESTIGATION - SUMMER 1991

Based on the findings outlined in sections 2.0 and 3.0 of this paper, follow-up monitoring was conducted to do more extensive sampling in the areas of highest contamination for arsenic and lead. This was to better determine the actual levels and extent of contamination.

Results from the summer re-sampling were received in September 1991 and confirmed earlier findings of antimony above decommissioning guidelines and levels of lead and arsenic above guidelines. Significantly higher levels of lead in the fishing area on the west bank of the Ganaraska were discovered, giving rise to human health concerns.

The area of lead contamination was ordered posted by the Medical Officer of Health on October 1, 1991. A Remedial Action Plan for the river harbour mouth is currently being discussed.

NOTES

1. Throughout this paper there are references to both Eldorado Resources Ltd. and Cameco Corporation.

Eldorado Gold Mines Limited set up a refinery at Port Hope in 1932. In June 1943, the company changed its name to Eldorado Mining and Refining Limited. In January 1944, the Federal Government took over the company and it became a Crown Corporation. In June 1968, the company changed its name to Eldorado Nuclear Limited. In 1988, Cameco Corporation was formed through the merger of Saskatchewan Mining Development Corporation and Eldorado Nuclear Limited. Both the Federal and Saskatchewan government's have planned to privatize Cameco by 1995.

2 Phytotoxic: poisonous to plants.

3 Radionuclide: a radioactive atom.

4 Upper Limit of Normal Guidelines were statistically-derived by taking the mean of available analytical results (minimum of 30 data points) for surface soil (0-5 cm depths) samples collected by MOE personnel from "background" (i.e. non point-source contaminated) sites in Ontario, and adding three standard deviations of the mean. Assuming the data are normally distributed, 99.7% of all contaminant concentration results for surface soil samples from background locations will lie below the ULN guidelines. For those distributions that are "non-normal", the calculated guidelines will not exactly correspond to the 99th percentile; however, they lie within the observed upper range of MOE results for background Ontario surface soil samples. Geometric means were not utilized because: 1) tests of representative non-normal distributions showed that normality was not significantly improved by using log-transformed data, and 2) the guideline concentrations calculated from the geometric mean were higher that the maximum observed concentrations.

5 Decommissioning refers to a situation where an industrial site is being converted for use as a residential or public access property such as a park.

MOE soil clean-up guideline numbers for use in site decommissioning were developed by the Phytoxicology Section of the Air Resources Branch, with input from Monenco Consultants, the Ministry of Labour, and the OMAF/MOE/MOH Sludge and Waste Utilization Committee. Initiation of guideline development occurred in 1984 at the request of Halton-Peel District MOE, who required guidelines for contaminants associated with oil refinery lands being decommissioned. Considerations of proposed land use made it desirable to have separate criteria for residential and industrial redevelopment.

"Guidelines for the Decommissioning and Cleanup of Sites in Ontario" was published by the Waste Management Branch of the Ministry of the Environment in February 1989. The decommissioning guidelines state that, in principle, remedial action is required wherever contaminants are present at concentrations above ambient background levels. It is the responsibility of the proponent to determine the ambient background level of contaminants in local area soils through a sampling program in consultation with MOE. Where local background levels are themselves unacceptably elevated due to industrial or other activity, the Upper Limit of Normal concentrations in soil data previously described may be used to define background levels.

[6] SYMAP - synigraphic computer mapping - used in conjunction with monitoring data it can produce contamination contour maps.

Complete copies of the ministry reports:

Phytotoxicology Assessment Surveys in the Vicinity of Eldorado Resources Ltd., Port Hope, 1986 and 1987 (MOE, Air Resources Branch - Phytotoxicology Section, May 1989)

and

Assessment of Human Health Risk of Reported Soil Levels of Metals and Radionuclides in Port Hope (MOE, Hazardous Contaminants Branch in consultation with the Health and Safety Support Unit - Ontario Ministry of Labour, 1991)

are available from:

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